UNIVERSITY OF WARSAW | FACULTY OF ECONOMIC SCIENCES

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Accounting for Substitutes in Single-Site Travel Cost Models with Limited Data

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MOTIVATION

Recreation values are needed — and they must be accurate

Recreation demand models turn trip taking behavior into value estimates that can be used for decisions.

Most of these uses require the estimates to be accurate:

- infrastructure feasibility assessment
- congestion management through access pricing
- balancing conservation with recreational access to protected areas
- a defensible lower bound on the economic value of a site

WHO THIS PAPER IS FOR

Applied practitioners who use TCM but do not have a nonmarket-valuation (or economics) background

Single-site models are widely used — often by researchers with no NMV or economics training. That is where better guidance has the potential for most leverage.

Accounting for substitutes in applied recreation demand research

Accounting for substitutes is crucial for accurate value estimates.

Models that omit substitutes can still be useful — just not for the purposes for which they are often wanted.

We already have models that naturally accommodate substitution (RUM / linked frameworks).

But their requirements make them awkward for much applied work:

- complexity — TCM's simplicity is one of its greatest advantages
- Intense data requirements and ex-ante knowledge of the choice set
- **together → single-site models that ignore substitutes dominate the applied literature**

THE GOAL OF THIS STUDY

To give applied researchers an ***out***:

Even if stuck with the data that you have ignoring substitutes is not the best you can do.

→ improve the quality of estimates in applied research.

So why not just use the advanced model?

Linked site-choice / count model

Hausman, Leonard & McFadden (1995)

Two-step decision: how many trips per season → which site for each trip.
Theoretically consistent — substitution is built in.

Requires:

- trip counts to every alternative
- travel costs to all sites
- a choice set defined up front
- higher respondent burden; simultane

The linked benchmark approach (LB)

Single-site count-data model

the applied workhorse

Models trips to the focal site only.
Substitution captured via travel costs to other sites as extra regressors.

Why it dominates applied work:

- shorter surveys, cheaper data
- substitutes can be appended ex post (Google Distance Matrix)
- **but: no agreed way to handle substitutes**

The choice is not "best model in theory" but "best feasible model in practice."

THE TAXONOMY

What approaches we compare against the benchmark

$$Trips_i = \exp(\beta_0 + \beta_1 * TC_i + \beta_2 * TC_{subst_i} + \beta * Z_i)$$

COMMON PRACTICE

NS **No Substitutes**

Omit substitutes entirely.

WN **Wide Net**

Include TC to all candidate substitutes.

MS **Minimum Substitute**

Include only the nearest substitute site.

PROPOSED ALTERNATIVES

FS **Filtered Substitutes**

Drop substitutes highly correlated with the focal site or each other.

PCA **PCA indices**

Replace substitute TCs with orthogonal principal components (≥97.5% variance).

Case study: Tatra National Park

> 25%	5,855	23
of all Polish national park visits	survey respondents	national parks covered

Choice set — mountain national parks. TNP (focal) + Babiogórski, Bieszczadzki, Gorczański, Gór Stołowych, Karkonoski, Magurski, Pieniński, Świętokrzyski — behaviorally comparable mountain recreation.

Online survey, Aug–Dec 2021, quota-sampled on age / gender / education / region.

Why this dataset is special: it contains multi-site visitation — so we can actually **build the linked benchmark** that single-site studies normally cannot. That is what makes the comparison in this paper possible.

Travel cost & value of travel time

Travel cost per individual–site

$$TC = 2k \cdot d + VOTT \cdot t$$

d — distance home→park (Google Distance Matrix)
t — one-way driving time
k — per-km cost (0.8358 PLN, 2021 official rate)

Six VOTT specifications

Rule-based

- VOTT_0 — zero (no time cost)
- VOTT_33 — ⅓ of wage rate
- VOTT_100 — full wage (if prefers shorter travel)

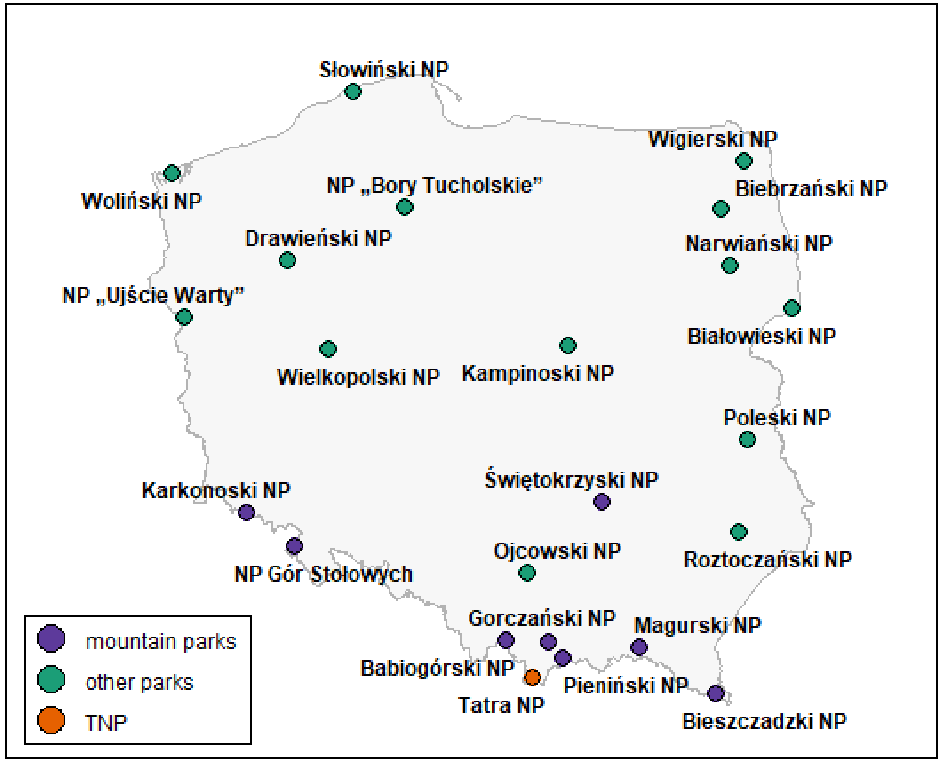
From a discrete choice experiment

- VOTT_MNL — multinomial logit (homogeneous)
- VOTT_MXL_d — mixed logit, uncorrelated
- **VOTT_MXL — mixed logit, correlated (preferred)**

Following Czajkowski et al. (2019)

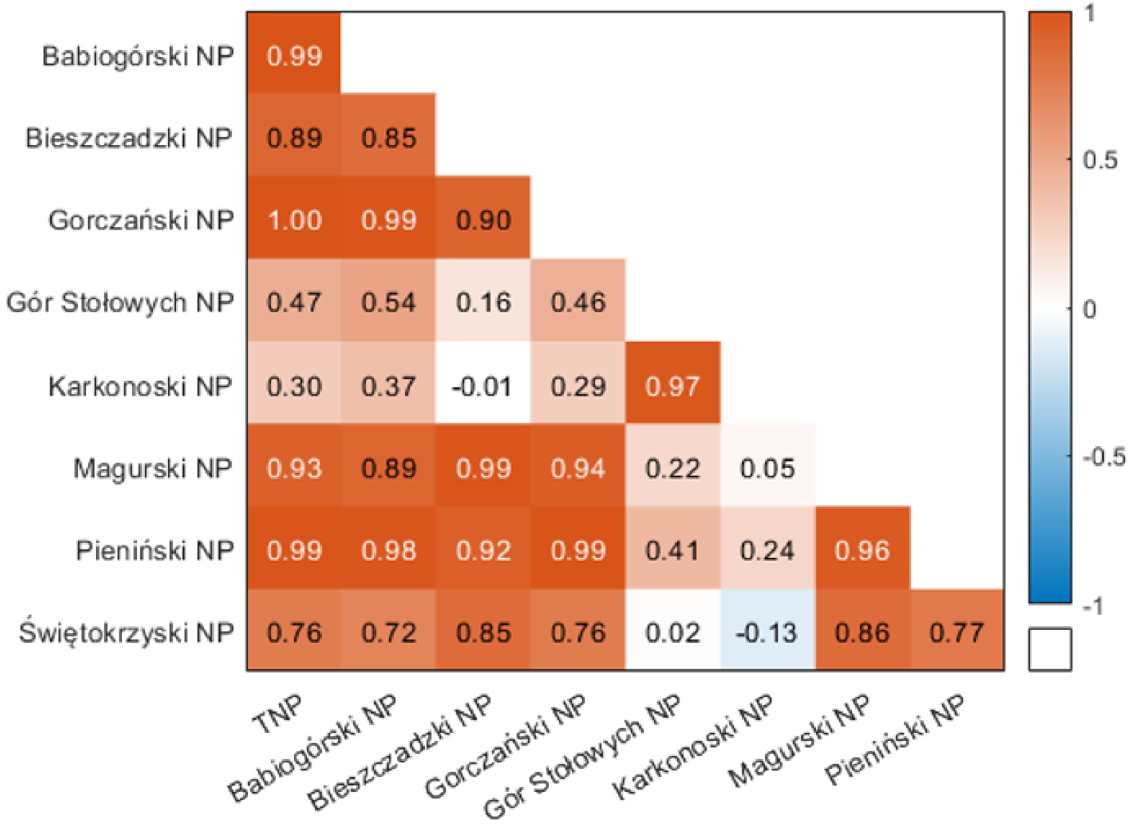
Six specifications by design: they let us isolate the effect of substitute treatment from assumptions about the value of travel time.

The collinearity structure of substitute prices



Travel costs are largely driven by distance — and mountain parks cluster.

The collinearity structure of substitute prices



Travel costs are largely driven by distance — and mountain parks cluster.

1. Many substitutes are highly correlated with TNP

→ overlapping spatial information → Wide-Net breaks down.

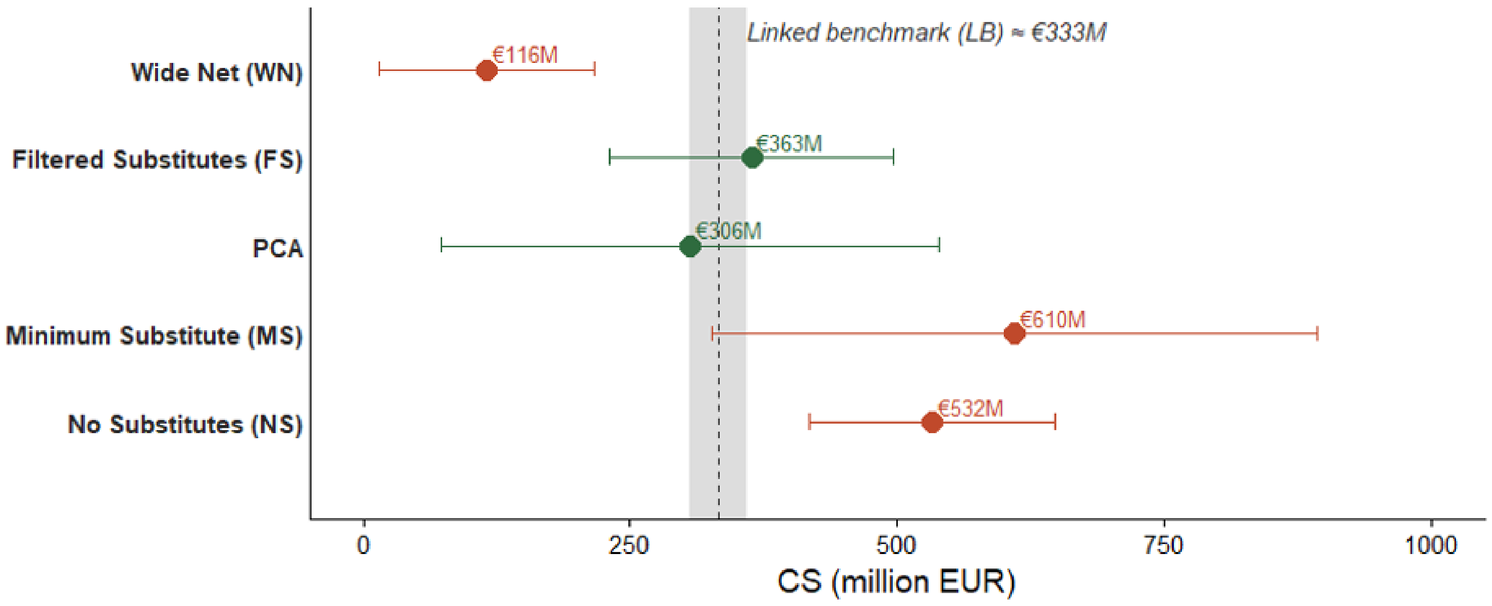
2. Low correlation with TNP ≠ independent of each other

e.g. Gór Stołowych & Karkonoski are distinct from TNP but 0.97 with each other.

So "keep the uncorrelated ones" is not enough — this motivates both the filtering threshold (FS) and orthogonalization (PCA).

Welfare estimates vs. the benchmark

Constrained specifications (FS, PCA) recover welfare closest to the linked benchmark (≈ €333M).



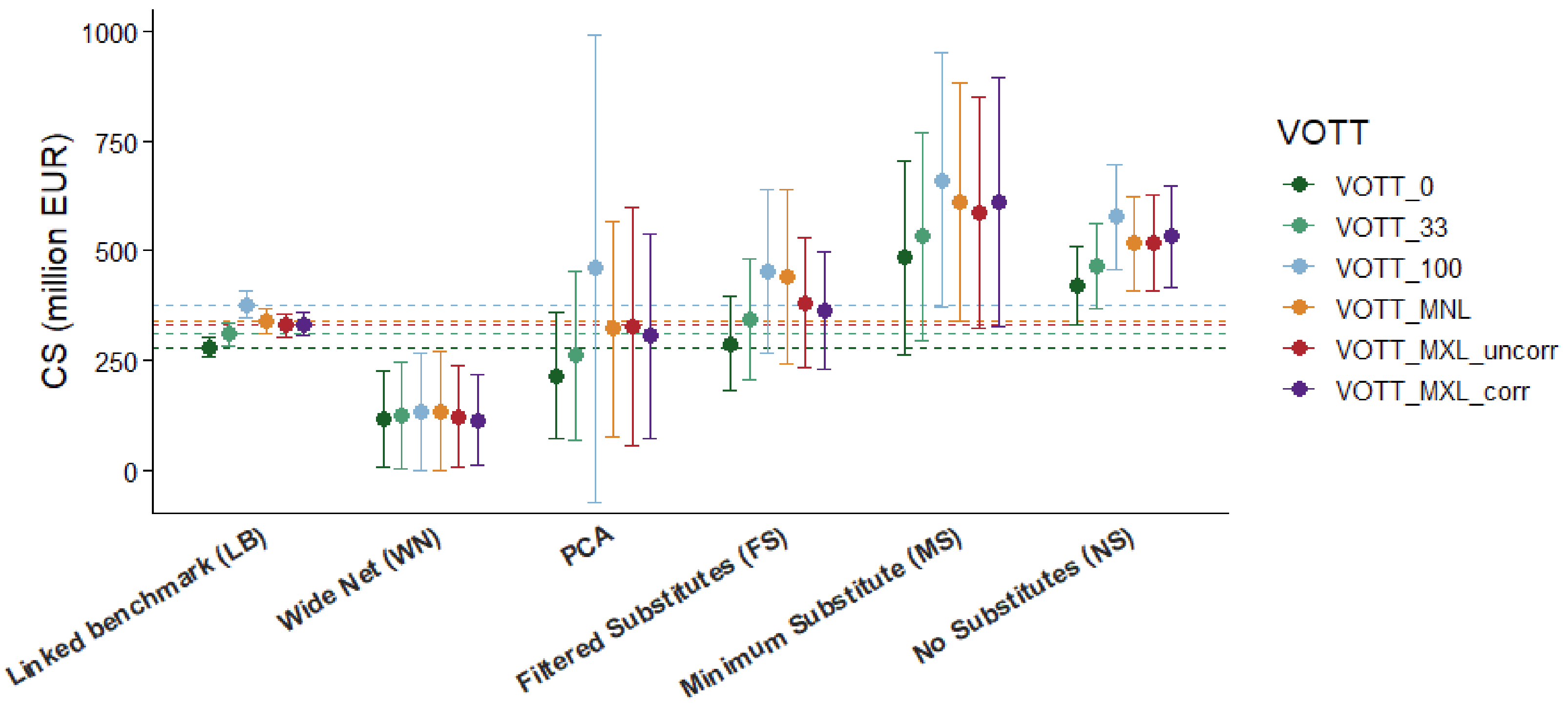
FS €363M · PCA €306M
closest to benchmark

NS €532M · MS €610M
inflated — displaced trips treated as lost

WN €116M
Can this be treated as a reliable lower bound?

Several hundred million euros of spread on the same park. Robustness across VOTT specifications next.

Ranking is stable across VOTT assumptions

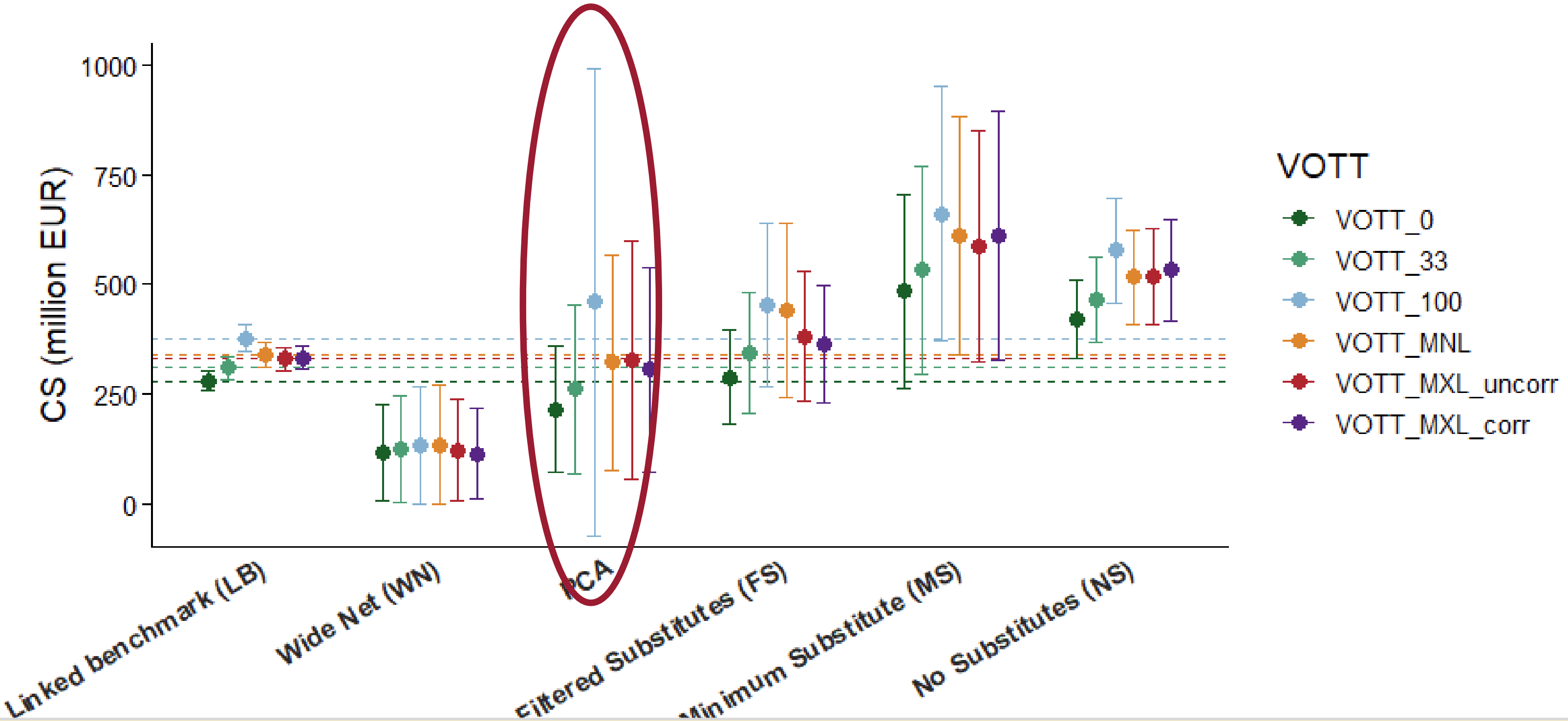


Levels shift with VOTT.
The ranking does not.

Moving from NS/MS to constrained controls changes welfare far more than switching VOTT within a spec.

RESULTS · 2 (ROBUSTNESS)

Ranking is stable across VOTT assumptions



Levels shift with VOTT.
The ranking does not.

Moving from NS/MS to constrained controls changes welfare far more than switching VOTT within a spec.

One exception worth a look: PCA under VOTT_100 — the confidence interval explodes. Why?

What's going on with VOTT_100?

What drives the explosion

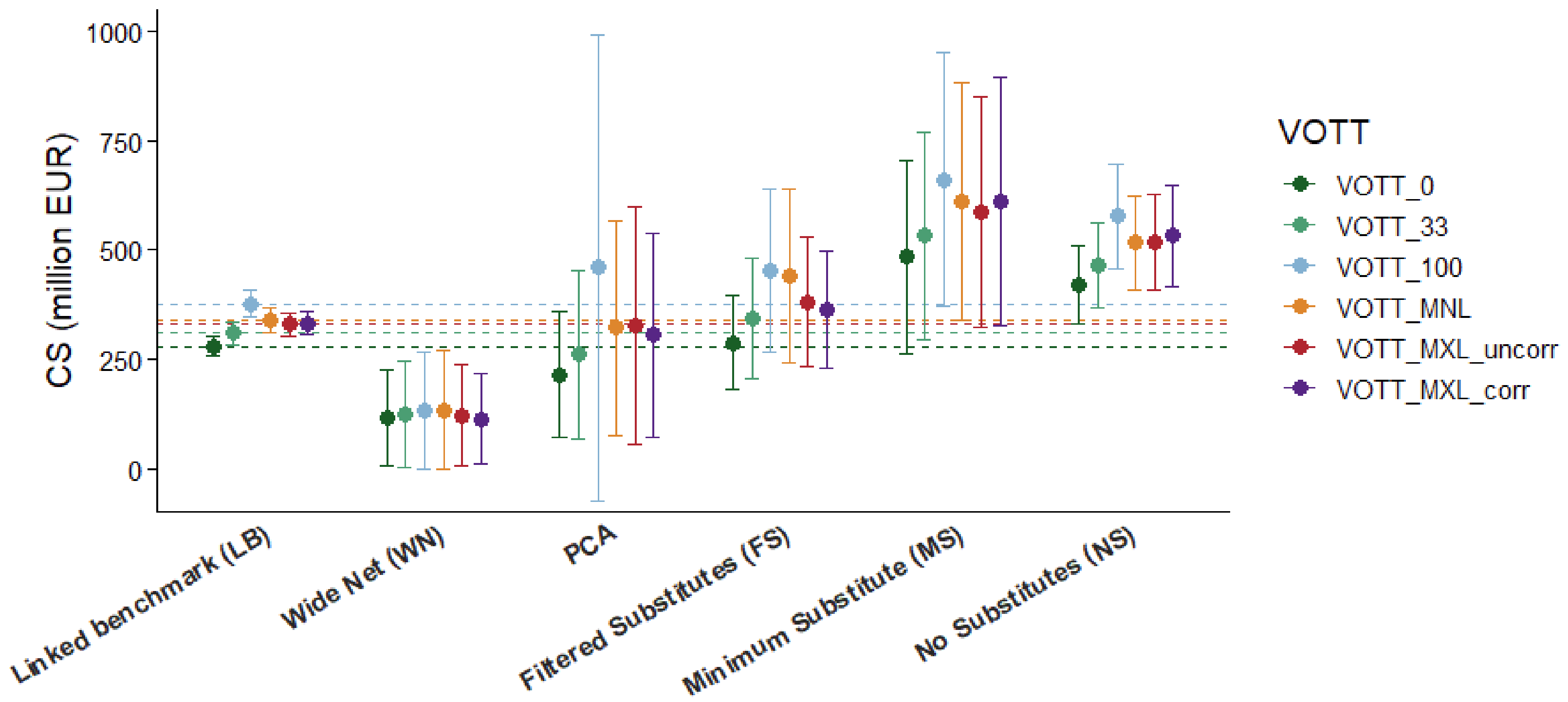
- PCA captures individual-level variation in travel cost, not in distances.
- Under VOTT_100, variation in VOTT is tied to number of trips.
- **→ the own-TC parameter loses precision (PCA1 and TC covariance jumps to 1250).**

	_0	_33	_100	_MNL	_MXL_d	_MXL
β TC	−0.901	−0.743	**−0.427**	−0.602	−0.636	−0.591
SE TC	0.307	0.277	**0.253**	0.232	0.248	0.248
corr coef	0.977	0.979	**0.984**	0.979	0.981	0.981
VIF	51.0	51.5	**69.3**	49.2	52.2	52.2
Covariance with TC_TNP						
PCA1	379	560	**1250**	479	675	642
PCA2	189	244	**399**	268	285	278
PCA3	−12	−10	**2**	−22	−12	−13

β TC / 100, EUR; correlation of PCA-reconstructed vs. actual own TC; PCA1–3 = variance of components.

Open question: we want actionable guidance for non-specialists. Is connecting one open issue (accounting for substitutes) with another (accounting for travel time) necessary — or a distraction?

Ranking is stable across VOTT assumptions



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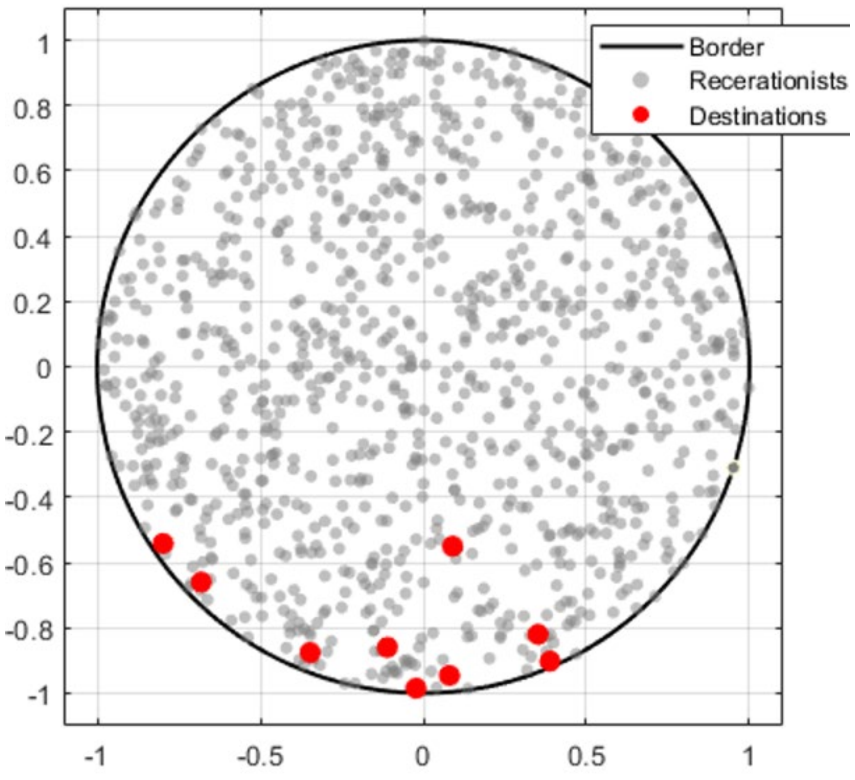
Does this generalize? Test it where truth is known



One replication (subset of individuals shown)

Why simulate?

In the field we never observe true welfare. Here we set it — and test whether the single-site shortcuts recover it.

Design

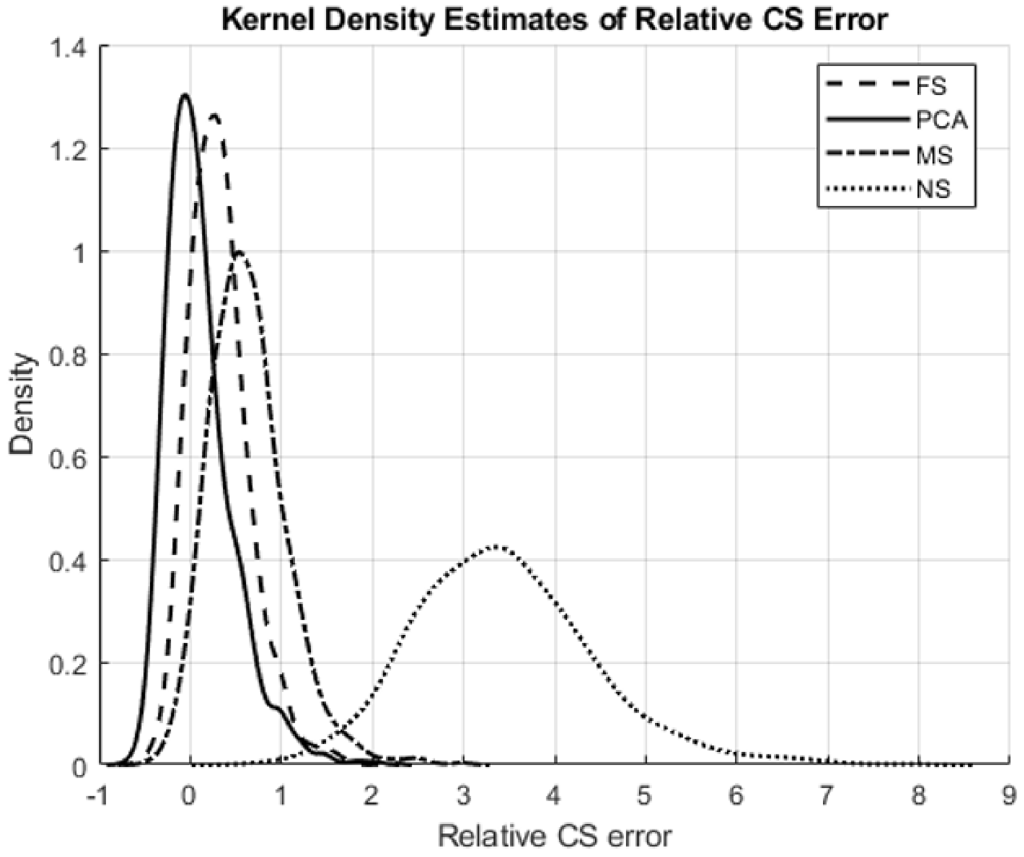
- 9 destinations fixed in a unit circle (≈ mountain-NP layout)
- 5,000 individuals drawn uniformly per replication
- Euclidean distance = travel cost
- **Two-step DGP = the linked structure itself**
- Estimate benchmark + all 5 single-site specs
- 1,000 replications · MATLAB MLE · SEs from inverse Hessian

Across 1,000 replications, constrained specs win

	Closest to LB	Convergence	Mean rel. err.	Summary
Wide Net (WN)	12.9%	13.7%	−0.75	Severe identification problems
Filtered Subst. (FS)	25.7%	100%	+0.32	Accurate; small upward bias
PCA	**52.5%**	**98.8%**	**+0.10**	**Most accurate; reliably stable**
Min. Substitute (MS)	8.9%	100%	+0.64	Systematic overestimation
No Substitutes (NS)	0%	100%	+3.44	Strong systematic overestimation

PCA closest to the benchmark in over half of replications; WN converges in only 14%. *Rel. err. = (CS_model − CS_benchmark) / CS_benchmark, averaged across replications.*

Validity vs. reliability, in one figure



Distribution of relative CS error across 1,000 replications. Zero = exact agreement with the benchmark.

- **PCA — centered & tight**

valid and reliable

- **FS — centered, slightly right**
- **NS / MS — biased but stable**

mass shifted right = systematic overstatement

- **WN — unstable (omitted: converges rarely)**

CONCLUSIONS

Take-aways — and open questions

GUIDANCE FOR PRACTITIONERS

1

Substitutes are a first-order choice
Similar-fit specs yield vastly different welfare. It's driven by substitution — not VOTT or demographics.

2

Common defaults fail predictably
NS/MS inflate welfare; WN destabilizes it. WN's low value is not "conservative."

3

Use a constrained specification
Diagnose the correlation structure first. Default to PCA; report FS alongside for site-level interpretability.

OPEN QUESTIONS

Substitutes × travel time
Is connecting one open issue (substitutes) with another (VOTT) necessary — or should it be kept simple

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...and yours

Credible welfare estimation is feasible under data constraints — if substitutes are specified responsibly.

Thank you · Key references

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Single site models' results